

Inductively Coupled Plasma – Atomic Emission Spectrometry – ICP-AES

Introduction

Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP) is a method of qualitative and quantitative analysis for elemental composition of samples. ICP analysis is based on the measurement of wavelengths and intensities of spectral lines emitted by secondary excitation. The Ocean Drilling Program (ODP) continually evaluated the analytical capabilities of the shipboard laboratories and decided to upgrade the analytical capability of the X-Ray Fluorescence (XRF) system by installing the ICP-AES instrument. In addition to analyzing hard rocks, the ICP system was used to analyze interstitial waters and sediments.

The Jobin-Yvon JY2000 instrument was installed in the Chemistry Laboratory on the *JOIDES Resolution* (JR) prior to Leg 187. Extensive testing was done during Leg 187 to evaluate the ICP system, create the ODP procedures for analyzing hard rock samples, and compare the results with duplicate analyses on the XRF. Overall, the analytical results were within the margin of error. Some advantages of using ICP included: samples could be analyzed more quickly; less sample material was required; and more trace elements could be measured reliably – lower detection limits. Additional procedures were developed on Legs 188 and 189 for analyzing interstitial water samples and sediments.

ICP Data Acquisition

The ICP works on the concept that excited electrons emit energy in narrow, well-defined wavelengths as they return to ground state. Characteristic wavelengths have been identified for many oxides and elements. The intensity of the energy at a given wavelength is proportional to the concentration of that element in the sample. The constituents of an unknown sample can be quantified by comparing the measured intensities to standards with known composition.

Sample preparation

ICP analysis required that the sample be in solution. Sediments and hard rocks had to be dissolved. A method similar to XRF sample preparation was developed to avoid having to deal with hydrofluoric acid in the shipboard environment. A washed and dried sample was powdered by crushing the sample between two plastic disks in a hydraulic press. Powder was produced by grinding pieces less than 1 cm in diameter in a Spex Shatterbox, using a tungsten carbide grinding vessel. (Procedures for producing powdered samples for XRF analyses.) Typically, 0.1 g of sample powder was mixed

with 0.4 g ultrapure grade of LiBO₂ flux and LiBr wetting agent in a Pt-Au crucible. This mixture was fused at 1050 °C for 10-12 minutes. After the bead cooled, it was dissolved in nitric acid. A small amount of filtered solution was diluted by additional nitric acid. This method was preferable and resulted in a stable sample solution that could be safely transported to scientists' home laboratories for additional study.

Interstitial water samples were much easier to prepare. The filtered interstitial water sample was acidified with dilute nitric acid, and then diluted again with deionized water. Undiluted interstitial water samples could be run, but care needed to be taken to not clog the nebulizer on the ICP.

Calibration

ICP analytical methods are based on comparison of the unknown sample's line intensities to one or more well-characterized standard reference materials. The calibration for the ICP needed to be performed on each run. For the hard rocks normally collected by ODP, there are a number of standards that have been used. The variability of sediment compositions precluded using a single standard. Sediments are often combinations of shales, carbonates, and siliceous deposits, so combinations of standards can be used to cover much of the spectral range. Table 1 contains many of the hard rock and sediment standards used by ODP for XRF and ICP analyses.

The standards used for calibration for interstitial water analyses must be constructed. The recommended method was to use filtered surface seawater spiked in order to create a master standard solution. The master standard solution could also be created using the IAPSO (International Association of Physical Science Organizations) standard seawater.

Table 1. Standard Reference Materials

ICP Standard Name	Replicate	Rock Type	Comment
152-11	A	MORB	
152-75	A	MORB	
AGV-1	A	Andesite	
AII-92-29-1	A	MORB/Basalt	
AII-92-29-1	X	MORB/Basalt	
AMERSIL	A	Blank for Bkg.	
BA-0500	A	Line Overlap Std.	
BA-1000	A	Line Overlap Std.	
BA-2000	A	Line Overlap Std.	
BAS-140	A	Diabase (504B)	
BAS-148	A	Basalt	
BE-N	A	Basalt	
BE-N (BR)	A	Alkali Basalt	
BE-N (PP)	A	Basalt	Pressed pellet
BHVO-1	A	Tholeiite/Basalt	
BHVO-1	B		
BHVO-1	TR1	Pressed pellet	
BHVO-2	A	Basalt	
BIR-1	A	Basalt	
BOB-1	A	MORB	
BR-1	A	Basalt	
CaCO ₃	A	Blank for Bkg.	ULTREX

ICP Standard Name	Replicate	Rock Type	Comment
CE-0500	A	Line Overlap Std.	
CE-1000	A	Line Overlap Std.	
CE-2000	A	Line Overlap Std.	
DNC-1	A	Diabase	
DR-N	A	Diorite	Leg 173, 12:1 ratio with Flux VII, NT-2100 bead
FE2O3	A	Blank for Bkg.	
Flux IX	A	Blank bead	
G-2	A	Granite	
G-2 (PP)	A	Granite	Pressed pellet
GBM-1	A	Garnet	
JA-1	A	Andesite	
JA-2	A	Andesite	
JA-3	A	Andesite	
JB-1A	A	Basalt	
JB-2	A	Basalt	
JB-3	B	Basalt	
JF-1	A	Feldspar	
JF-2	A	Feldspar	
JG-1a	A	Granite	MAJOR
JG-1a	B	Granodiorite	TRACE
JG-2	A	Granite	
JG-3	A	Granodiorite	
JGB-1	A	Gabbro	
JP-1	A	Peridotite	
JR-1	A	Rhyolite	
JR-2	A	Rhyolite	
K1919	A	Tholeiite	
LI2B407	A	Blank for Bkg.	
MAG-1	A	Sediment	
MGO	A	Blank for Bkg.	
Mica-Fe	A	Biotite	
Mica-Mg	A	Phlogopite	
MRG-1	A	Gabbro	
NBS-1c	A	Limestone	
NBS-278	A	Obsidian	
NBS-688	A	Basalt	
NIM-D	A	Dunite	
NIM-P	A	Pyroxenite	
PCC-1	A	Peridotite	
RB-0500	A	Line Overlap Std.	
RB-1000	A	Line Overlap Std.	
RB-2000	A	Line Overlap Std.	
RGM-1	A	Rhyolite	
SCo-1	A	Shale	
SCo-1	B	Cody Shale	Pressed Pellet
SCo-1	TR1	Pressed pellet	
SCo-1	X	Cody Shale	
SDC-1	A	Mica Schist	
SR-0500	A	Line Overlap Std.	
SR-1000	A	Line Overlap Std.	
SR-2000	A	Line Overlap Std.	
STM-1	A	Syenite	
SY-2	A	Syenite	
TI-0500	A	Line Overlap Std.	
TI-1000	A	Line Overlap Std.	
TIO2-9.3%	A	Line Overlap Std.	
UB-N	A	Serpentinite	Leg 173, 12:1 ratio with Flux VII, NT-2100 bead
UB-N (PP)	A	Serpentinite	Pressed pellet
V-0500	A	Line Overlap Std.	
V-1000	A	Line Overlap Std.	
V-2000	A	Line Overlap Std.	
W-2	A	Diabase	
Y-0500	A	Line Overlap Std.	
Y-1000	A	Line Overlap Std.	
Y-2000	A	Line Overlap Std.	

Data acquisition

The analytical run should begin within 10 minutes of the end of the calibration run. The first sample was the master drift sample – analyzed at the beginning and again at the end of the run. Preliminary results were calculated by the system software, but the complete data reduction had to be done by the scientists. Data were loaded into an Excel spreadsheet which had many of the necessary calculations already set up.

A more complete discussion on procedures for collecting ICP-AES data can be found in *ODP Technical Note 29: Analysis of Major and Trace Elements in Rocks, Sediments, and Interstitial Waters by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES)*.

Data Archive

Janus ICP Data Format

Because the data collected on the ICP system were very similar to data collected on the XRF system, ICP data for hard rocks and sediments were archived in the same tables as the XRF data. Interstitial water data were entered into the tables with the other interstitial water analyses.

ICP major oxide and trace element data can be retrieved from Janus Web by using a predefined query. The ICP Atomic Emission Spectrometry (ICP-AES) query webpage allows the user to extract data using the following variables to restrict the amount of data retrieved: leg, site, hole, core, section, depth range, or latitude and longitude range. Occasionally, replicate samples were analyzed for the major oxides; those data, when available, were uploaded separately. The web query reports the replicate data on separate lines. In addition, the trace element data will also be reported on a separate line, even though trace element data were collected at the same time as the major oxide data.

Table 2 lists the data fields retrieved from the Janus database for the ICP predefined query. The first column contains the data item; the second column indicates the Janus table or tables in which the data were stored; the third column is the Janus column name or the calculation used to produce the value. Appendix II contains additional information about the fields retrieved using the Janus Web ICP query and the data format for the archived ASCII files.

Table 2. ICP-Atomic Emission Spectrometry – (ICP-AES) query

Item Name	Janus Table	Janus Column Name and Calculation
Leg	SECTION	Leg
Site	SECTION	Site
Hole	SECTION	Hole
Core	SECTION	Core
Type	SECTION	Core_type
Section	SECTION	Section_number
Top (cm)	SAMPLE	Top_interval x 100
Bottom (cm)	SAMPLE	Bottom_interval X 100
Depth (mbsf)	DEPTH_MAP, SAMPLE	DEPTH_MAP.Map_Interval_Top + SAMPLE.Top_interval
Run	XRF_SAMPLE	XRF_Run_Identifier
Replicate	XRF_SAMPLE	XRF_Replicate
Bead Loss on Ignition	XRF_SAMPLE	Bead_LOI
Silica – SiO ₂ (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – SiO2::XRF_Analysis_Result
Titanium Oxide – TiO ₂ (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – TiO2::XRF_Analysis_Result
Aluminum Oxide – Al ₂ O ₃ (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Al2O3::XRF_Analysis_Result
Iron Oxide - Fe ₂ O ₃ * (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Fe2O3*::XRF_Analysis_Result
Manganese Oxide - MnO (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – MnO::XRF_Analysis_Result
Magnesium Oxide - MgO (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – MgO::XRF_Analysis_Result
Calcium Oxide - CaO (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – CaO::XRF_Analysis_Result
Sodium Oxide - Na ₂ O (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Na2O::XRF_Analysis_Result
Potassium Oxide - K ₂ O (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – K2O::XRF_Analysis_Result
Phosphorus Pentoxide - P ₂ O ₅ (wt %)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – P2O5::XRF_Analysis_Result
Niobium - Nb (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Nb::XRF_Analysis_Result
Zirconium - Zr (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Zr::XRF_Analysis_Result
Yttrium - Y (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Y::XRF_Analysis_Result
Sulfur - S (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – S::XRF_Analysis_Result
Strontium - Sr (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Sr::XRF_Analysis_Result
Rubidium - Rb (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Rb::XRF_Analysis_Result
Scandium - Sc (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Sc::XRF_Analysis_Result
Molybdenum - Mo (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Mo::XRF_Analysis_Result
Beryllium - Be (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Be::XRF_Analysis_Result
Thorium - Th (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Th::XRF_Analysis_Result
Cobalt - Co (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Co::XRF_Analysis_Result
Gadolinium - Gd (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Gd::XRF_Analysis_Result
Dysprosium - Dy (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Dy::XRF_Analysis_Result
Erbium - Er (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Er::XRF_Analysis_Result
Ytterbium - Yb (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Yb::XRF_Analysis_Result
Hafnium - Hf (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Hf::XRF_Analysis_Result
Lead - Pb (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Pb::XRF_Analysis_Result
Gallium - Ga (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Ga::XRF_Analysis_Result
Zinc - Zn (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Zn::XRF_Analysis_Result
Copper - Cu (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Cu::XRF_Analysis_Result
Nickel - Ni (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Ni::XRF_Analysis_Result
Chromium - Cr (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Cr::XRF_Analysis_Result
Vanadium - V (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – V::XRF_Analysis_Result
Cerium - Ce (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Ce::XRF_Analysis_Result
Barium - Ba (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Ba::XRF_Analysis_Result
Cesium - Cs (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Cs::XRF_Analysis_Result
Lanthanum - La (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – La::XRF_Analysis_Result
Neodymium - Nd (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Nd::XRF_Analysis_Result
Samarium - Sm (ppm)	XRF_SAMPLE_ANALYSIS	XRF_Analysis_Code – Sm::XRF_Analysis_Result
Sample Type	XRF_SAMPLE_TYPE	Sample_Type
Comment	XRF_SAMPLE	XRF_Comment

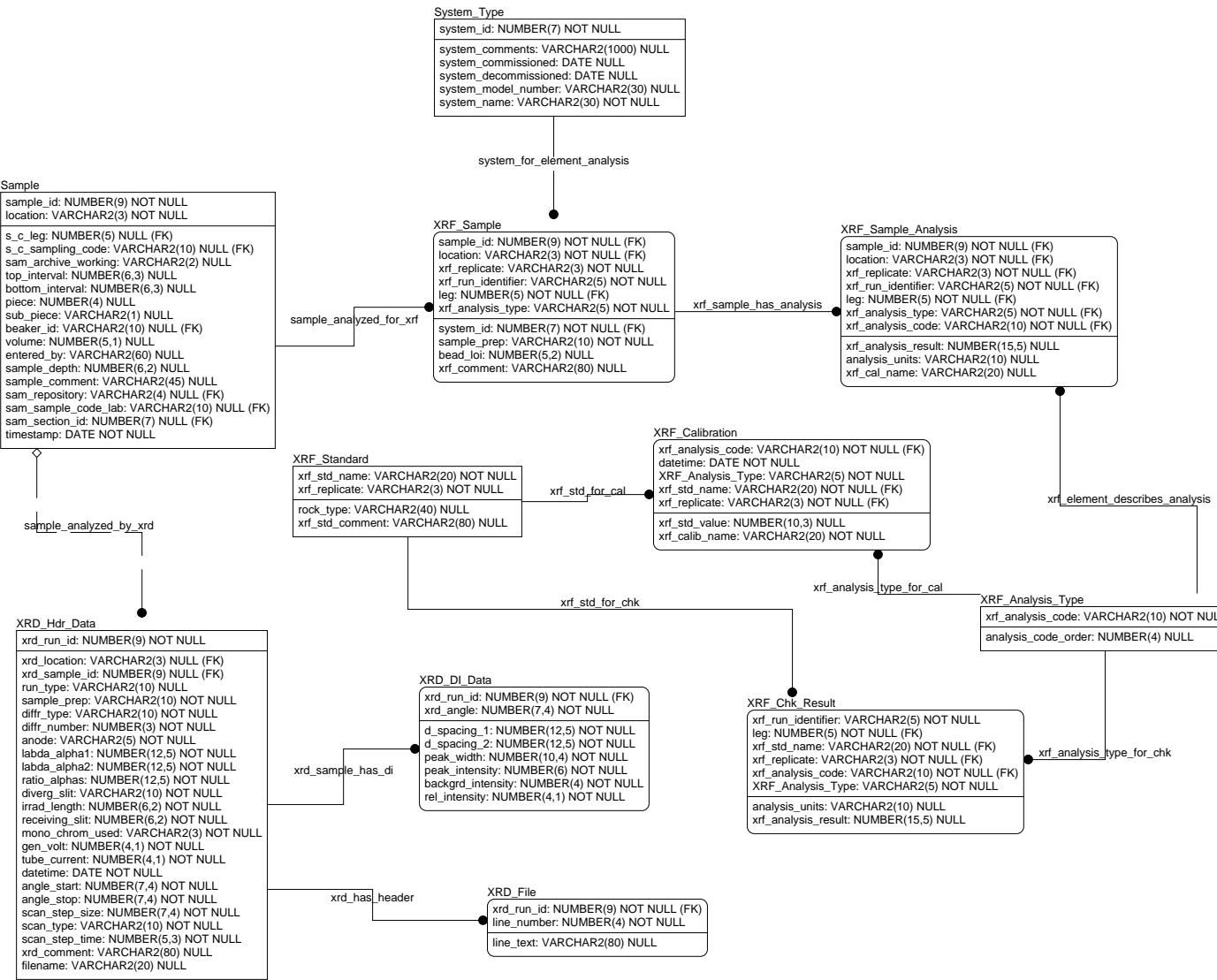
Data Quality

The quality of the ICP data was considered very good, even though the ship environment was a difficult environment to get accurate measurements. ICP analyses done on volcanic, mafic and ultramafic samples are the highest quality because there are standards that characterize the range of elemental concentrations most often found in these types of rocks. It is more difficult to create standards that would encompass the range of elemental concentrations found in sedimentary environments.

In order to aid the interpretation of ICP analyses, an additional column of information was added to the XRF_SAMPLE table after ICP data were being archived in Janus. This column, Sample_type, was added to allow scientists to describe the type of rock that was analyzed, and in turn, would allow scientists to extract data based on specific rock types. These data were not usually stored in the original data files, and it was necessary to extract that information from the Initial Report volumes. Due to constraints of time, it was not possible to complete entering this information.

Reference

Murray, R.W., Miller, D.J., Kryc, K.A., 2000. Analysis of major and trace elements in rocks, sediments, and interstitial waters by inductively coupled plasma-atomic emission spectrometry (ICP-AES). *ODP Tech. Note 29*.



Appendix I: Janus Data Model – ICP-Atomic Emission Spectrometry (ICP-AES)
 [archived in XRF tables].

ICP-Atomic Emission Spectrometry – (ICP-AES)		
Table Name	Column Name	Column Comment
XRF_Sample	sample_id	Oracle-generated sequence number that with <i>location</i> uniquely identifies a sample.
	location	Code that indicates which Janus application assigned the sample_id. Values are SHI (ship), GCR (Gulf Coast Repository), ECR (East Coast Repository, WCR (West Coast Repository) and BCR (Bremen Core Repository). Used with <i>sample_id</i> to uniquely identify a sample.
	XRF_replicate	Identifier for each replicate of a sample to allow all to be entered into the database.
	XRF_run_identifier	Operator-assigned run identifier. Must be unique during a leg.
	leg	Number identifying the cruise for which data were entered into the database.
	XRF_analysis_type	Type of analysis performed on an ICP sample -- MAJOR oxide, TRACE element.
	system_id	Unique identifier for a system of equipment used to collect data.
	sample_prep	Type of preparation used for a sample - a fused glass disc (bead) or pressed pellet (pellet).
	bead_loi	Loss on Ignition. The percentage of weight lost after igniting the ICP bead [(post_ign_sample_wt/pre_ign_sample_wt)-1]*(-100).
	XRF_comment	General comment about sample or analysis.
XRF_Sample_Analysis	sample_id	Oracle-generated sequence number that with <i>location</i> uniquely identifies a sample.
	location	Code that indicates which Janus application assigned the sample_id. Values are SHI (ship), GCR (Gulf Coast Repository), ECR (East Coast Repository, WCR (West Coast Repository) and BCR (Bremen Core Repository). Used with <i>sample_id</i> to uniquely identify a sample.
	XRF_replicate	Identifier for each replicate of a sample to allow all to be entered into the database.
	XRF_run_identifier	Operator-assigned run identifier. Must be unique during a leg.
	leg	Number identifying the cruise for which data were entered into the database.
	XRF_analysis_type	Type of analysis performed on an ICP sample -- MAJOR oxide, TRACE element.
	XRF_analysis_code	The code for the element or oxide being analyzed.
	XRF_analysis_result	Analytical result for an analysis code.
	analysis_units	Measurement units used for an analysis. Major oxides - wt%; Trace elements - ppm.
	XRF_cal_name	The same description as the attribute XRF_calib_name, but allowed to be null.
XRF_Analysis_Type	XRF_analysis_code	The code for the element or oxide being analyzed.
	analysis_code_order	Used to determine the order that analysis codes will appear on a spreadsheet or report.
XRF_Sample_Type	sample_type_id	ID assigned to the rock type.
	sample_type	Rock type name, e.g., Basalt, Granite, Oxide Gabbro.
XRF_Standard	XRF_std_name	The name of an ICP standard.
	XRF_replicate	Identifier for each replicate of a sample to allow all to be entered into the database.
	rock_type	Description of the rock type or material of the standard.
	XRF_std_comment	Comment about an ICP standard.
XRF_Calibration	XRF_analysis_code	The code for the element or oxide being analyzed
	datetime	Generic date/time. Often used for keys when multiple comments, etc can be entered.
	XRF_Analysis_Type	Type of analysis performed on an ICP sample -- MAJOR oxide, TRACE element.

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Table Name	Column Name	Column Comment
	XRF_std_name	The name of an ICP standard
	XRF_replicate	Identifier for each replicate of a sample to allow all to be entered into the database.
	XRF_std_value	The expected results for a element in an ICP standard
	XRF_calib_name	Name associated with a particular calibration.

XRF_Chk_Result	XRF_run_identifier	Operator-assigned run identifier. Must be unique during a leg.
	leg	Number identifying the cruise for which data were entered into the database.
	XRF_std_name	The name of an ICP standard.
	XRF_replicate	Identifier for analysis replicates of a standard to allow all to be entered into the database.
	XRF_analysis_code	The code for the element or oxide being analyzed.
	XRF_Analysis_Type	Type of analysis performed on an ICP sample -- MAJOR oxide, TRACE element.
	analysis_units	Measurement units used for an analysis. Major oxides - wt%; Trace elements - ppm.
	XRF_analysis_result	Analytical result for an analysis code.

Section	section_id	Unique Oracle-generated sequence number to identify each section. This is done because of the physical subsection / zero section problems. In adding new sections, deleting sections or changing sections - don't want to have to renumber.
	leg	Number identifying the cruise for which data were entered into the database.
	site	Number identifying the site from which the core was retrieved. A site is the position of a beacon around which holes are drilled.
	hole	Letter identifying the hole at a site from which a core was retrieved or data were collected.
	core	Sequential numbers identifying the cores retrieved from a particular hole. Cores are generally 9.5 meters in length, and are numbered serially from the top of the hole downward.
	core_type	A letter code identifying the drill bit/coring method used to retrieve the core.
	section_number	Cores are cut into 1.5 m sections. Sections are numbered serially, with Section 1 at the top of the core.
	section_type	Used to differentiate sections of core (S) from core catchers (C). Previously core catchers were stored as section CC, but in Janus core catchers are given the next sequential number from the last section recovered.
	curated_length	The length of the section core material, in meters. This may be different than the liner length for the same section. Hard rock cores will often have spacers added to prevent rock pieces from damaging each other.
	liner_length	The original length of core material in the section, in meters. Sum of liner lengths of all the sections of a core equals core recovery.
	core_catcher_stored_in	Sometimes the core catcher is stored in a D tube with a section. core_catcher_stored_in contains the section number of the D tube that holds the core catcher.
	section_comments	Comments about this section

Sample	sample_id	Oracle-generated sequence number that with <i>location</i> uniquely identifies a sample.
	location	Code that indicates which Janus application assigned the sample_id. Values are SHI (ship), GCR (Gulf Coast Repository), ECR (East Coast Repository), WCR (West Coast Repository) and BCR (Bremen Core Repository). Used with <i>sample_id</i> to uniquely identify a sample.
	s_c_leg	Number identifying the cruise for which data were entered into the database. Foreign key used with <i>s_c_sampling_code</i> to link samples with a scientist's sample request.
	s_c_sampling_code	Code used to identify samples taken for a sample request. Used with <i>s_c_leg</i> .
	sam_archive_working	Part of section where sample was taken. Valid values: WR – whole round, A – archive half, W – working half.
	top_interval	Distance in meters from the top of the section to the top of the sample.

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Table Name	Column Name	Column Comment
	bottom_interval	Distance in meters from the top of the section to the bottom of the sample.
	piece	Additional identifier for hard rock samples. Each individual piece of rock within a section is numbered consecutively starting at the top of the section.
	sub_piece	Additional identifier for hard rock samples. When a piece is broken, the individual fragments are given consecutive letter designations. Note that subpiece assignments must be made in conjunction with piece numbers.
	beaker_id	The number on the moisture density beaker. Used for samples analyzed for moisture and density.
	volume	Volume of sample.
	entered_by	Indicates who entered the sample into the database.
	sample_depth	Depth of the sample.
	sample_comment	Comment about the sample.
	sam_repository	Repository where sample was taken. Valid values SHIP (ship), GCR (Gulf Coast Repository), ECR (East Coast Repository), WCR (West Coast Repository) and BCR (Bremen Core Repository).
	sam_sample_code_lab	Code to indicate the shipboard lab that will perform the initial analysis.
	sam_section_id	Unique Oracle-generated sequence number to identify each section. This is a foreign key that links a sample to leg, site, hole, core, and section.
	timestamp	Date and time when sample was entered into database. Samples taken before November 25, 1998 and migrated samples have the timestamp 11/25/1998 12:26 PM

System_Type	system_id	Unique identifier for a system of equipment used to collect data.
	system_comments	Comments associated with a piece of analytical equipment
	system_commissioned	Date when a piece of equipment was deployed to collect scientific data for the ODP.
	system_decommissioned	Date when a piece of analytical equipment was no longer used by the ODP.
	system_model_number	The model number of a piece of equipment used for scientific analysis.
	system_name	The name for a piece of equipment used for analysis.

Appendix II. Description of Data Items from ICP query.

Column Name	Column Description	Format
Leg	Number identifying the cruise. The ODP started numbering the scientific cruises of the <i>JR</i> at Leg 101. A leg was nominally two months duration. During the 18+ years of the ODP, there were 110 cruises on the <i>JR</i> .	Integer 3
Site	Number identifying the site. A site is the location where one or more holes were drilled while the ship was positioned over a single acoustic beacon. The <i>JR</i> visited 656 unique sites during the course of the ODP. Some sites were visited multiple times, including some sites originally visited during the Deep Sea Drilling Program for a total of 673 site visits.	Integer 4
Hole	Letter identifying the hole. Multiple holes could be drilled at a single site by pulling the drill pipe above the seafloor, moving the ship some distance away and drilling another hole. The first hole was designated 'A' and additional holes proceeded alphabetically at a given site. Location information for the cruise was determined by hole latitude and longitude. During ODP, there were 1818 holes drilled or deepened.	Text 1
Core	Cores are numbered serially from the top of the hole downward. Cored intervals are up to 9.7 m long, the maximum length of the core barrel. Recovered material was placed at the top of the cored interval, even when recovery was less than 100%. More than 220 km of core were recovered by the ODP.	Integer 3
Type	All cores are tagged by a letter code that identifies the coring method used.	Text 1
Section	Cores are cut into 1.5 m sections in order to make them easier to handle. Sections are numbered serially, with Section 1 at the top of the core. GRA measurements were made on sections. Core Catcher sections identified as "CC".	Integer 2 (Text 2)
Top (cm)	The top interval of a measurement in centimeters measured from the top of a section.	Decimal F5.1
Bottom (cm)	The bottom interval of a measurement in centimeters measured from the top of a section.	Decimal F5.1
Depth (mbsf)	Distance in meters from the seafloor to the measurement location.	Decimal F7.3
Run	Run identifier assigned by shipboard scientists or lab technician to identify a given batch of samples.	Text 5
Replicate	Split of a sample	Text 3
Bead Loss on Ignition	Loss on Ignition. The percentage of weight lost after igniting the ICP bead $[(\text{post_ign_sample_wt}/\text{pre_ign_sample_wt}) - 1] * (-100)$.	Decimal F5.2
Silica – SiO ₂ (wt %)	Analytical result for major oxide Silica in weight percent.	Decimal F15.5
Titanium Oxide – TiO ₂ (wt %)	Analytical result for major Titanium oxide in weight percent.	Decimal F15.5
Aluminum Oxide – Al ₂ O ₃ (wt %)	Analytical result for major Aluminum oxide in weight percent.	Decimal F15.5
Iron Oxide – Fe ₂ O ₃ * (wt %)	Analytical result for major Iron oxide in weight percent.	Decimal F15.5
Manganese Oxide – MnO (wt %)	Analytical result for major Manganese oxide in weight percent.	Decimal F15.5
Magnesium Oxide – MgO (wt %)	Analytical result for major Magnesium oxide in weight percent.	Decimal F15.5
Calcium Oxide – CaO (wt %)	Analytical result for major Calcium oxide in weight percent.	Decimal F15.5
Sodium Oxide – Na ₂ O (wt %)	Analytical result for major Sodium oxide in weight percent.	Decimal F15.5
Potassium Oxide – K ₂ O (wt %)	Analytical result for major Potassium oxide in weight percent.	Decimal F15.5
Phosphorus Pentoxide – P ₂ O ₅ (wt %)	Analytical result for major Phosphorus Pentoxide in weight percent.	Decimal F15.5
Niobium - Nb (ppm)	Analytical result for trace element Niobium in parts per million.	Decimal F15.5
Zirconium - Zr (ppm)	Analytical result for trace element Zirconium in parts per million.	Decimal F15.5
Yttrium - Y (ppm)	Analytical result for trace element Yttrium in parts per million.	Decimal F15.5
Sulfur - S (ppm)	Analytical result for trace element Sulfur in parts per million.	Decimal F15.5
Strontium - Sr (ppm)	Analytical result for trace element Strontium in parts per million.	Decimal F15.5
Rubidium - Rb (ppm)	Analytical result for trace element Rubidium in parts per million.	Decimal F15.5
Scandium - Sc (ppm)	Analytical result for trace element Scandium in parts per million.	Decimal F15.5

Column Name	Column Description	Format
Molybdenum - Mo (ppm)	Analytical result for trace element Molybdenum in parts per million.	Decimal F15.5
Beryllium - Be (ppm)	Analytical result for trace element Beryllium in parts per million.	Decimal F15.5
Thorium - Th (ppm)	Analytical result for trace element Thorium in parts per million.	Decimal F15.5
Cobalt - Co (ppm)	Analytical result for trace element Cobalt in parts per million.	Decimal F15.5
Gadolinium - Gd (ppm)	Analytical result for trace element Gadolinium in parts per million.	Decimal F15.5
Dysprosium - Dy (ppm)	Analytical result for trace element Dysprosium in parts per million.	Decimal F15.5
Erbium - Er (ppm)	Analytical result for trace element Erbium in parts per million.	Decimal F15.5
Ytterbium - Yb (ppm)	Analytical result for trace element Ytterbium in parts per million.	Decimal F15.5
Hafnium - Hf (ppm)	Analytical result for trace element Hafnium in parts per million.	Decimal F15.5
Lead - Pb (ppm)	Analytical result for trace element Lead in parts per million.	Decimal F15.5
Gallium - Ga (ppm)	Analytical result for trace element Gallium in parts per million.	Decimal F15.5
Zinc - Zn (ppm)	Analytical result for trace element Zinc in parts per million.	Decimal F15.5
Copper - Cu (ppm)	Analytical result for trace element Copper in parts per million.	Decimal F15.5
Nickel - Ni (ppm)	Analytical result for trace element Nickel in parts per million.	Decimal F15.5
Chromium - Cr (ppm)	Analytical result for trace element Chromium in parts per million.	Decimal F15.5
Vanadium - V (ppm)	Analytical result for trace element Vanadium in parts per million.	Decimal F15.5
Cerium - Ce (ppm)	Analytical result for trace element Cerium in parts per million.	Decimal F15.5
Barium - Ba (ppm)	Analytical result for trace element Barium in parts per million.	Decimal F15.5
Cesium - Cs (ppm)	Analytical result for trace element Cesium in parts per million.	Decimal F15.5
Lanthanum - La (ppm)	Analytical result for trace element Lanthanum in parts per million.	Decimal F15.5
Neodymium - Nd (ppm)	Analytical result for trace element Neodymium in parts per million.	Decimal F15.5
Samarium - Sm (ppm)	Analytical result for trace element Samarium in parts per million.	Decimal F15.5
Sample Type	Type of rock or sediment, e.g., Basalt, Gabbro, Sediment	Text 40
Comment	Comment about the ICP analysis or additional information about the sample type.	Text 80